APPENDIX FT - FLIGHT TEST PROCEDURES

NOTE: This Appendix contains Flight Test procedures that can be used to validate the operation of an FGS consistent with the update to AC/ACJ 1329. The expectation is that the FAA would integrate this material in an update to AC 25-7 – Flight Test Guide.

The JAA will include this material as an AMJ Number 2 to JAR 25.1329.

FT.1 General

A flight test program should be established that confirms the performance of the FGS for the modes of operation and the operational capabilities supported by its design. The operational implications of certain failures and Failure Conditions may require flight evaluation. The pilot interface with FGS controls and displays in the cockpit will need to be assessed.

Some aspects of the design may be validated by laboratory test and/or simulator evaluation. It is recommended that an applicant provide a certification flight demonstration plan to the authorities at a timely point in development program.

The scope of the flight demonstration program will be dependent on the operational capability being provided including any new and novel features. Early coordination with the regulatory authorities is recommended to reduce certification risks associated with the flight demonstration program.

The intent of the flight demonstration program is to confirm that the operation of the FGS is consistent with its use for the intended flight operations of the airplane type and configuration.

The modes of the FGS should be demonstrated in representative airplane configurations and under a representative range of flight conditions.

The following are specific test procedure that can assist in that demonstration program.

FT.2 Protection Features

Protection feature are included in the design of an FGS to assist the flight crew in ensuring that boundaries of the flight envelope or operational limits are not exceeded leading to an unsafe condition. The means to alert the flight crew to a condition or for the system to intervene to preclude the condition may vary but certain operational scenarios can be used to assess the performance of the system in providing the protection function. The following procedures can be used to evaluate the protection functions of an FGS.

FT2.1 Low Speed Protection

The low speed protection feature in an FGS is intended to prevent loss of speed to an unsafe condition [Refer to AC/ACJ 25.1329 – Section 10.4.1]. This may be accomplished by a number of means but should be evaluated under a number of scenarios.

There are four cases that should be considered when evaluating when the Low Speed Protection function of a FGS:

1. <u>High Altitude Cruise Evaluation</u>.

   a) At high altitude at normal cruise speed, engage the FGS into an Altitude Hold mode and a Heading or LNAV mode.

   b) Engage the autothrust into a speed mode.

c) Manually reduce one engine to idle thrust

d) As the airspeed decreases, observe the FGS behavior in maintaining altitude and heading/course

e) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

2. Altitude Capture Evaluation at low altitude.

a) At about 3000 feet MSL and 250 knots, engage the FGS into Altitude Hold and a Heading or LNAV mode.

b) Engage the autothrust into a speed mode.

c) Set the Altitude Pre-selector to 8000 feet MSL.

d) Make a flight level change to 8000 feet with a 250 knots climb at maximum climb power.

e) When the FGS first enters the altitude capture mode, retard an engine to idle power.

f) As the airspeed decreases, observe the airplane trajectory and behavior.

g) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operations.

3. High Vertical Speed Evaluation.

a) Engage the FGS in Vertical Speed Mode with a very high rate of climb.

b) Set the thrust to a value that will cause the airplane to decelerate at about 1 knot per second.

c) As the airspeed decreases, observe the airplane trajectory and behavior.

d) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

4. Approach Evaluation.

a) Conduct an instrument approach with vertical path reference.

b) Couple the FGS to the localizer and glideslope (or LNAV/VNAV, etc.).

c) Cross the Final Approach Fix/Outer Marker at a high-speed (approximately V_{ref} + 40 knots) with the thrust at idle power until low speed protection activates.

d) As the airspeed decreases, observe the airplane trajectory and behavior.

e) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciation for acceptable operation.

f) Note the pilot response to the alert and the recovery actions taken to recover to the desired vertical path and the re-capture to that path and the acceleration back to the desired approach speed.

NOTE: If the FGS remains in the existing mode with reversion to Low Speed Protection, the FGS must provide a suitable alert to annunciate the low speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to accelerate back to the desired approach speed.

FT.2.2 High-speed Protection

The high-speed protection feature in an FGS is intended to prevent a gain in airspeed to an unsafe condition [Refer to AC/ACJ 25.1329 – Section 10.4.2]. This may be accomplished by a number of means but should be evaluated under a number of scenarios.

There are three cases that should be considered when evaluating the High-speed protection function of a FGS:.

1. High Altitude Level Flight Evaluation with Autothrust function

   a) Select Autothrust Off (if an automatic wake-up function is provided; otherwise, select Autothrust on).

   b) Engage the FGS in altitude hold

   c) Select a thrust level that will result in an acceleration beyond V_{MO}/M_{MO}

   d) As the airspeed increases, observe the behavior of the High-speed protection condition and any autothrust reactivation and thrust reduction, as applicable.

   e) Assess the performance of the FGS to control the airspeed to V_{MO}/M_{MO}, or other appropriate speed.

2. High Altitude Level Flight Evaluation without Autothrust function

   a) Select a thrust value that will result in acceleration beyond V_{MO}/M_{MO} .

   b) As the airspeed increases, observe the basic airplane overspeed warning activate between V_{MO} + 1 and V_{MO} + 6 knots.

   c) Observe the high-speed protection condition become active as evidenced by the unique visual alert and note possible FGS mode change.

   d) Maintain the existing thrust level and observe the airplane depart the selected altitude.

   e) After sufficient time has elapsed to verify and record FGS behavior has elapsed, reduce the thrust as necessary to cause the airplane to begin a descent.

   f) Observe the FGS behavior during the descent and subsequent altitude capture at the original selected altitude.

3. High Altitude Descending Flight Evaluation with Autothrust function

   a) Select Autothrust Off (with automatic wake-up function) with thrust set to maintain airspeed 10% below V_{MO}/M_{MO} with the FGS engaged in altitude hold

   b) Select vertical speed mode that will result in acceleration beyond V_{MO}/M_{MO}

   c) As the airspeed increases observe the autothrust function reactivate and reduce thrust towards idle

   d) Observe the activation of FGS high-speed protection condition

e) Observe the reduction in pitch

GENERAL NOTE: If the FGS remains in the existing mode with reversion to High Speed Protection, the FGS must provide a suitable alert to annunciate the high speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to decelerate back to the desired speed

FT.3 Environmental Conditions

Some environmental conditions have created operational problems during FGS operations. It should be the objective of the flight demonstration program to expose the FGS to a range of environmental conditions as the opportunity presents itself. These include winds, windshear, mountain-wave, turbulence, icing, etc. However, some specific test conditions may have to be created to emulate operational conditions that are not readily achieved during normal flight test.

FT.3.1 Icing

The accumulation of ice on the airplane wings and airframe can have an effect on airplane characteristics and FGS performance. FGS operations may mask the onset of an airplane configuration that would present the pilot with handling difficulties when resuming manual control, particularly following any automatic disengagement of the FGS.

During the flight test program the opportunity should be taken to evaluate the FGS during natural icing conditions including the shedding of the ice, as applicable.

It is recommended that the opportunity should be taken to evaluate the operation of the FGS during basic airplane evaluation with 'ice shapes'.

The following conditions should be considered for evaluating FGS performance under 'icing conditions':

(a) "Holding ice" as defined by JAR/FAR 25 Appendix C (Note - subject of future NPA/NPRM action)

(b) Medium to light weight, symmetric fuel loading

(1) High lift devices retracted configuration:

Slow down at 1 knot/sec to automatic autopilot disengage, stall warning or entry into speed protection function.

Recovery should be initiated a reasonable period after the onset of stall warning or other appropriate warning. The airplane should exhibit no hazardous characteristics.

(2) Full Instrument Approach:

If the autopilot has the ability to fly a coupled instrument approach and go-around, it should demonstrate the following:

(i) Instrument approach using all normal flap selections.

(ii) Go-around using all normal flap selections.

(iii) Glideslope capture from above the glidepath.

(3) If the airplane accretes or sheds ice asymmetrically it should be possible to disengage the autopilot at any time without unacceptable out of trim forces.

(4) General maneuverability including normal turns, maximum angle of bank commanded by the FGS in one direction and then rapid reversal of command reference to the maximum FGS angle of bank in the other direction.

FT.4 Failure Conditions

This section contains criteria relating to airplane system Failure Conditions identified for validation by a system Safety Assessment.

FT.4.1 Test Methods

The test method for most Failure Conditions will require some type a fault simulation technique with controls that provide for controlled insertion and removal of the type of fault identified as vulnerability. The insertion point will typically be at a major control or guidance point on the airplane (e.g., control surface command, guidance command, thrust command).

The implication of the effect of the Failure Condition on various flight phases should be assessed and the demonstration condition established. This assessment should identify the parameters that need to be measured and the instrumentation required.

The role of any monitoring and alerting in the evaluation should be identified.

The alertness of the crew to certain airplane response cues may vary with phase of flight and other considerations. Guidance on this is provided below.

The 'success criteria' or operational implications should be identified and agreed with the regulatory authority prior to the conduct of the test. Guidance on this is provided below.

FT.4.2 Fault Recognition and Pilot Action

The Safety Assessment process may identify a vulnerability to the following types of Failure Condition:

- hardover
- slowover
- oscillatory

The various types of effect will cause differing response in the airplane and resultant motion and other cues to the flight crew to alert them to the condition. The flight crew attention may be gained by additional alerting provided by systems on the airplane. The recognition is then followed by appropriate action including recovery.

The assessment of the acceptability of the Failure Condition and the validation of the Safety Assessment assumptions are complete when a stable state is reached as determined by the test pilot.

The following paragraphs provide guidance for specific phases of flight.

FT.4.2.1 Takeoff

This material addresses the use of a FGS after rotation for takeoff.

Section 13 identified the key considerations for this phase of flight to be the effect on the net flight path and the speed control after liftoff. Automatic control is not typically provided for the takeoff roll. It may however be selected soon after liftoff. Failure Conditions may be introduced with this engagement.

For the initial liftoff through flap retraction, it can be assumed that the flight crew is closely monitoring the airplane movements and a maximum crew response time after recognition would be one second.

FT.4.2.2 Climb, Cruise, Descent and Holding and Maneuvering

The demonstration of applicable failure conditions during these phases of flight would include the potential for occupants to be out of their seats and moving about the cabin.

FT.4.2.3 Approach

There are two types of approach operations to consider – an approach with and without vertical path reference. The approach with vertical path reference will be assessed against ground-based criteria using a deviation profile assessment. A height loss assessment is used for approaches without vertical path reference

FT.4.2.3.1 Fault Demonstration Process

The worst case malfunction has first to be determined, based on factors such as:

- i) Failure Conditions identified by the system safety assessment
- ii) System characteristics such as variations in authority or monitor operation
- iii) Mitigation provided by any system alerts
- iv) Aircraft flight characteristics relevant to failure recognition

Once the worst-case malfunction has been determined, flight tests of the worst-case malfunction should be flown in representative conditions (e.g. coupled to an ILS), with the malfunction being initiated at a safe height. The pilot should not initiate recovery from the malfunction until one second after the recognition point. The delay is intended to simulate the variability in response to effectively a "Hands off" condition. It is expected that the pilot will follow through on the controls until the recovery is initiated..

FT.4.2.3.2 Assessment – Approach with Vertical Path Reference

Figure FT-1 provides a depiction of the deviation profile method. The first step is to identify the deviation profile from the worst case malfunction. The next step is to 'slide' the deviation profile down the glidepath, until it is tangential to the 1:29 line or the runway. The Failure Condition contribution to the Minimum Use Height may be determined from the geometry of the aircraft wheel height determined by the deviation profile, relative to the 1:29 line intersecting a point 15 feet above the threshold. The method of determination maybe by graphical or by calculation.

NOTE: The Minimum Use Height is based on the recovery point because:

- i) It is assumed that in service the pilot will be "Hands off" until the autopilot is disengaged at the Minimum Use Height in normal operation.
- ii) The test technique assumes a worst case based on the pilot being "Hands off" from the point of malfunction initiation to the point of recovery.
- iii) A failure occurring later in the approach than the point of initiation of the worst case malfunction described above is therefore assumed to be recovered earlier and in consequence to be less severe.

FT.4.2.3.3 Assessment – Approach without Vertical Path Reference

Figure FT-2 provides a depiction of the height loss method. A descent path of three degrees, with nominal approach speed, should be used unless the autopilot is to be approved for significantly steeper descents. The vertical height loss is determined by the deviation of the aircraft wheel height relative to the nominal wheel flight path.

.

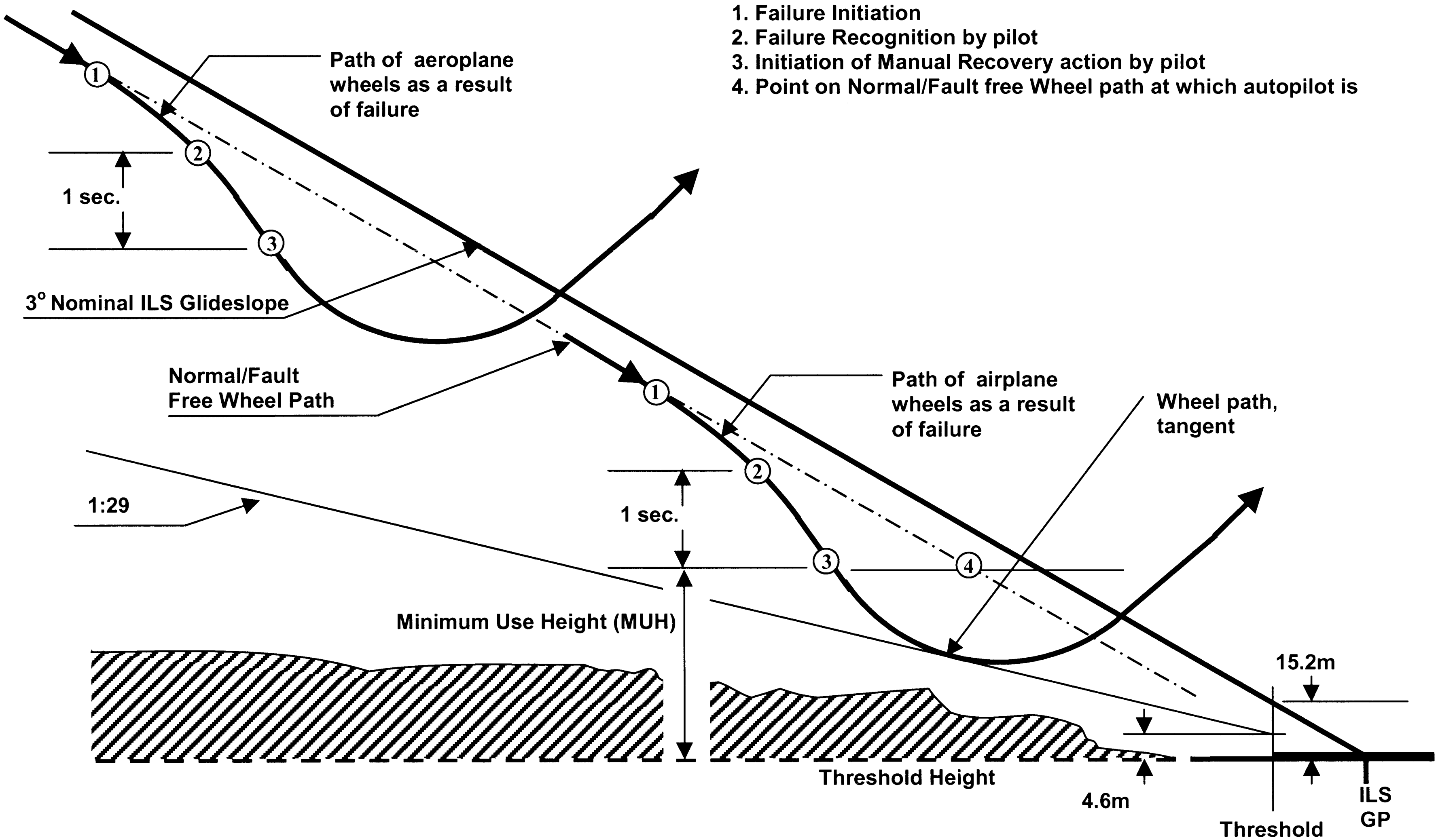

Figure FT – 1 Deviation Profile Method

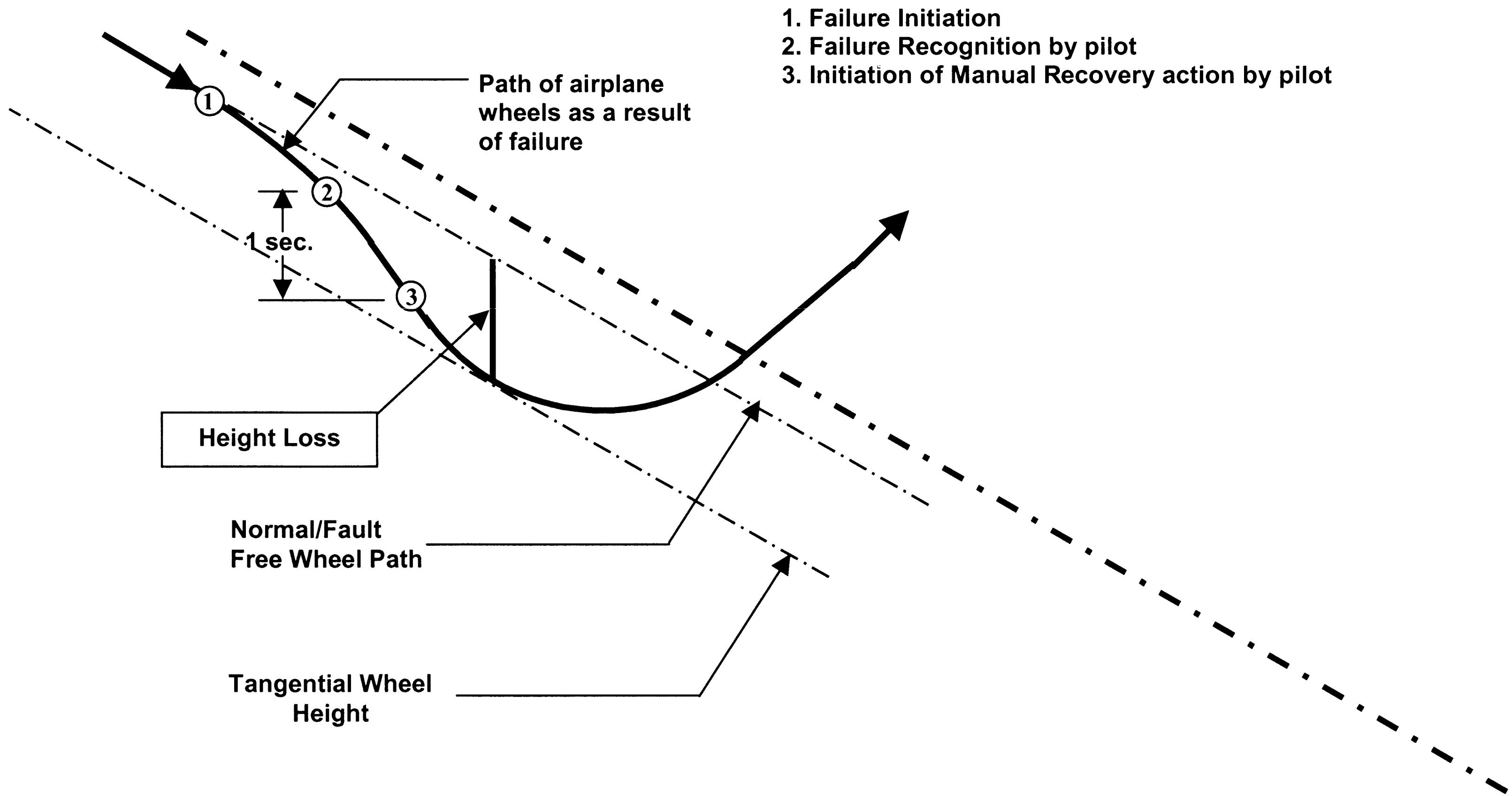

Figure FT – 2 Height Loss Method

FT.4.3 Autopilot Override

The initial tests to demonstrate compliance should be accomplished at an intermediate altitude and airspeed e.g. 15000 feet MSL and 250 knots. With the autopilot engaged in altitude hold, the pilot should apply a low force to the control wheel (or equivalent) and verify that the automatic trim system does not produce motion resulting in a hazardous condition. The pilot should then gradually increase the applied force to the control wheel (or equivalent) until the autopilot disengages. When the autopilot disengagement occurs, observe the transient response of the airplane. Verify that the transient response is in compliance with Section 8.4.

Disengagement caused by flight crew override should be verified by applying an input on the control wheel (or equivalent) to each axis for which the FGS is designed to disengage, i.e. the pitch and roll yoke, or the rudder pedals (if applicable). The inputs by the pilot should build up to a point where they are sharp and forceful, so that the FGS can immediately be disengaged for the flight crew to assume manual control of the airplane.

If the autopilot is designed such that it does not automatically disengage during an autopilot override and instead provides a flight deck Alert to mitigate any potentially hazardous conditions, the timeliness and effectiveness of this Alert. The pilot should follow the evaluation procedure identified above until such time as an Alert is provided. At that time, the pilot should respond to the Alert in a responsive manner consistent with the level of the alert (i.e., a Caution, a Warning) and with the appropriate flight crew procedure defined for that Alert. When the autopilot is manually disengaged, observe the transient response of the airplane and verify that the transient response is in compliance with Section 8.4.

> **NOTE**:: During hardover testing as described in Chapter 6 of AC 25-7A there will be several opportunities throughout the flight envelope to conduct these tests. The evaluation of the manual disconnects would include the forces required for an autopilot disengage, (not too light, but not too high,), the transients characteristics associated with each one (i.e., what type of motion and "g's" that are produced), and the warnings that are generated.

After the initial tests have been successfully completed, the above tests should be repeated at higher altitudes and airspeeds until reaching M_{MO} at high cruise altitudes.